View Highlight

7643 - Paerl, Wilhelm, Boyer - Ensuring Sustainability of Lakes

Highlight ID: 19851, Version: AC/GPA

Background: Man-made nutrient over-enrichment (eutrophication) in freshwater systems has led to a global proliferation of harmful blue-green algal (cyanobacterial) blooms (CyanoHABs) which foul waterways and water intakes, disrupt food webs, fuel hypoxia, and produce secondary metabolites that are toxic to water consumers and users, including zooplankton, fish, shellfish, cattle, domestic pets, and humans. This problem is exacerbated by global warming, which favors CyanoHABs (Paerl and Huisman *Science* 320:57-58 (2008); Paerl and Huisman *Environmental Microbiology Reports* 1:27-37 (2009)). CyanoHABs threaten the use and sustainability of the world's largest lake ecosystems, including the Great Lakes, Lakes Okeechobee and Ponchartrain in North America, the large lakes of Africa, Asia and South America, and drinking water reservoirs worldwide. Particularly affected are the rapidly developing regions of Southeast Asia, typified by China's 3rd largest lake, Taihu, a previously pristine, revered lake supplying the drinking water needs of over 20 million people (**Fig. 1**). In recent years, Taihu has experienced CyanoHABs so severe that human water use has had to be curtailed, leading to a highly publicized drinking water crisis in 2007 (Guo *Science* 317:1166 (2007); Qin et al. *Environmental Management* (2009) (**Fig. 2**). This project employs an interdisciplinary (ecology, toxicology, water management), international (USA-China) team to assess, control and mitigate CyanoHABs threatening the sustainability of Taihu.

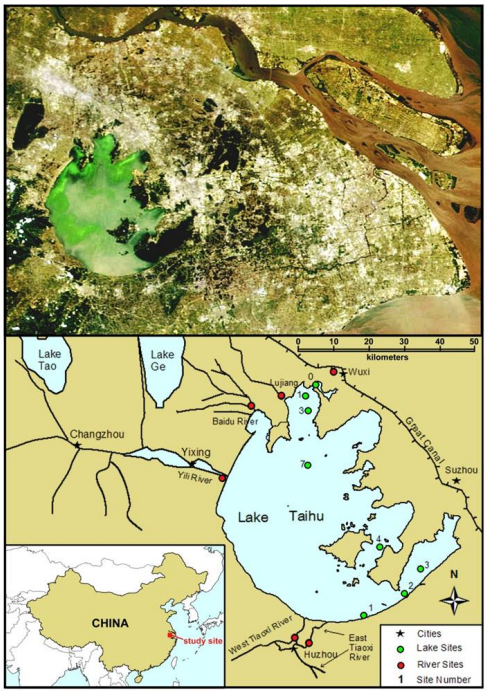

Figure 1. ***Location of Lake Taihu in eastern China and MODIS remote sensing image, showing the 2007 CyanoHAB bloom.***

Image Provided by: hpaerl@email.unc.edu
Credit: Hans Paerl, University of North Carolina at Chapel Hill, Institute of Marine Sciences

Results: Researchers from the University of North Carolina at Chapel Hill, the University of Tennessee - Knoxville, and China conducted seasonal *in situ* nutrient addition and dilution bioassays in 2008 and 2009 to determine which nutrient(s) (nitrogen, phosphorus) promote CyanoHABs, primarily the toxin producer *Microcystis* spp. Bioassays revealed that *both* nitrogen (N) and phosphorus (P) inputs control the growth of CyanoHABs; in the spring when algal production is increasing P is limiting, and in the summertime, when CyanoHABs prevail, N availability controls the bloom potential. Hence, a dual nutrient reduction strategy will likely be needed to control eutrophication and bloom outbreaks in Taihu (Hai et al. *Limnol. Oceanogr.* in press). During May and October 2009, at the onset and end of the bloom, respectively, nutrient dilution bioassays were deployed to determine input reductions needed to bring the lake below the bloom threshold. Preliminary indications are that at least a 50% reduction of *both* N and P will be needed. During 2010, the researchers will determine the seasonal distributions of these reductions. The results from bioassays, in addition to being published, are made available to Chinese provincial and central government environmental management agencies (Jiangsu Province, Chinese EPA, Chinese NSF and Academy of Sciences). The interactive effects of climate change, specifically warming, on CyanoHAB dynamics is also being investigated (Paerl and Huisman 2008, 2009). Lastly, microscopic, molecular and toxicological analyses were conducted in 2009 to determine which CyanoHAB species are producing toxins (there are at least 3 species of *Microcystis* present,as well as *Anabaena* spp.), and hence warrant attention from water quality management and environmental health perspectives (Wilhelm et al. in preparation; Otten et al. in preparation). These analyses further ensure that certain CyanoHABs are not replaced by other harmful species once wastewater and agricultural/industrial nutrient reduction efforts, and hydrologic modifications, including flushing of the lake with nearby Yangtze River water, are implemented.

Lake Taihu serves as a "looking glass" for formulating nutrient input reductions and long-term management strategies in large lake ecosystems threatened by proliferating CyanoHABs (Paerl et al. 2008). This research project provides a scientific basis for long-term CyanoHAB management in large lakes worldwide.

Figure 2. ***Two views of the 2009 Microcystis spp. Bloom, taken by P.I. Paerl during October, 2009.***

Image Provided by: hpaerl@email.unc.edu
Credit: Hans Paerl, University of North Carolina at Chapel Hill, Institute of Marine Sciences

Publications thus far resulting from this project:

Hai, X., H. W. Paerl, B. Qin, G. Zhu, G. Gao. 2009. Nitrogen and phosphorus inputs control phytoplankton growth in eutrophic Lake Taihu, China. *Limnology and Oceanography* (in press).

Paerl, H.W. and J. Huisman. 2008. Blooms like it hot. *Science* 320:57-58.

Paerl, H.W., E.S. Calandrino, and J. Huisman. 2008. Global expansion of harmful cyanobacterial blooms in water supplies due to human development and climate change. In, P.C. Singer, and B. Kirsch (Eds) Proceedings of Symposium *"Safe and Sustainable Drinking Water in Developing and Developed Countries."* UNC-Chapel Hill Institute for the Environment, Chapel Hill, NC, Nov. 2008.

Paerl, H.W. and J. Huisman. 2009. Climate Change: A Catalyst for Global Expansion of Harmful Cyanobacterial Blooms. *Environmental Microbiology Reports* 1(1):27-37.

Qin, B. G. Zhu, G. Gao, Y. Zhang, W. Li, H.W. Paerl, and W.W. Carmichael. 2009. A drinking water

crisis in Lake Taihu, China: Linkage to climatic variability and lake management. *Environmental Management* (DOI 10.1007/s00267-009-9393-6).

This highlight addresses the strategic outcome goals of the **NSF Strategic Plan 2006-2011** as follows:

1. Primary Strategic Outcome Goal: Discovery: This research program is focused on transforming the knowledge base of US researchers on developing response strategies to the proliferation of cyanobacterial harmful algal blooms (CyanoHABs) in US water supplies. Through collaborations with and observation of efforts by colleagues at the Chinese Academy of Sciences (Nanjing Instit. of Geography and Limnology) and, the intent is both a discovery and learning process that will provide currently unavailable infrastructure to deal with future CyanoHAB events in North America. These efforts will help researchers investigate and document approaches to dealing with massive scale CyanoHAB events that are anticipated to ultimately impact the overall use, ecological integrity and safety of North American surface waters.

2. Secondary Strategic Outcome Goals: Learning: Secondary strategic goals are to develop sustainable resource management approaches that will prevent efforts (outlined in the primary goal) from pressing natural resources beyond a "tipping point" where one CyanoHAB species is replaced by another potentially harmful (or even more harmful) species. The development of such strategies is currently not part of the educational and research efforts used to develop science-based HAB mitigation strategies and management approaches.

Primary Strategic Outcome Goal: Discovery

- International
- Biology
- Engineering

Secondary Strategic Outcome Goals: Learning

- Undergraduate Education and Undergraduate Student Research
- Graduate Education and Graduate Student Research
- International Research Experiences for Undergraduate & Graduate Students
- Public Understanding of Science and Lifelong Learning

Does this highlight represent potentially transformative research? *If so, please explain why. For more information, see Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008 and Important Notice 130: Transformative Research*

Yes

This transformative program of research, education and partnership with Chinese researchers is providing a novel "looking glass" into how future CyanoHAB events might be dealt with in North American systems. The program will collect valuable information needed for the long term sustainability of North American water supplies, and will foster further development and strengthening of the global partnership between American and Chinese researchers. This program will provide researchers with the opportunity to examine potential CyanoHAB scenarios for North American surface water supplies that are predicted to occur 10 - 50 years in the future.

What is the intellectual merit of this activity?

This research project is developing a process-based, ecologically and economically-sound approach for long-term control of CyanoHABs, which have caused massive problems for industry, recreation and tourism and has disrupted regional drinking water supplies. While events in China may seem half-way-around-the-world relative to local concerns, they are in fact a potential foreshadowing for North American waterways. Moreover, dramatic responses planned by the Jiangsu Provincial EPA and the Chinese National EPA represent novel opportunities to test mitigation and control approaches to CyanoHAB events that cannot currently be tested in North America (since there are no events of this scale, yet). This project will evaluate these approaches by deploying *in situ* bioassays and by examining microbial communities with advanced molecular tools to determine nutrient input thresholds below which CyanoHAB growth and proliferation can be controlled in a regime of changing climatic conditions.

What are the broader impacts of this activity?
Merit Review Broader Impacts Criterion: Representative Activities, July 2007

Figure 3. *P.I. Paerl, collecting water samples from Lake Taihu, October, 2009.*

Image Provided by: hpaerl@email.unc.edu
Credit: Hans Paerl, University of North Carolina at Chapel Hill, Institute of Marine Sciences

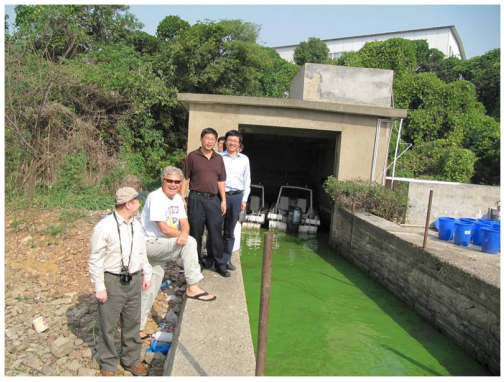

Figure 4. *P.I. Paerl with Chinese (Academy of Sciences) colleagues at Lake Taihu, October, 2009.*

Image Provided by: hpaerl@email.unc.edu
Credit: Hans Paerl, University of North Carolina at Chapel Hill, Institute of Marine Sciences

Figure 5. *P.I.s Paerl, Boyer and Wilhelm, with students and Chinese colleagues setting up and deploying in situ nutrient bioassays at Lake Taihu during May, 2009.*

Image Provided by: hpaerl@email.unc.edu
Credit: Hans Paerl, University of North Carolina

- *How well does the proposed activity broaden the participation of underrepresented groups (e.* at Chapel Hill, Institute of Marine Sciences *g., gender, ethnicity, disability, geographic, etc?)*
- *What may be the benefits of the proposed activity to society?*
- *How well does the activity advance discovery and understanding while promoting teaching, training, and learning?*
- *Will the results be disseminated broadly to enhance scientific and technological understanding?*

1. How well does the proposed activity **broaden the participation of underrepresented groups**? (e.g., gender, ethnicity, disability, geographic, etc?)

This project directly broadens research participation of underrepresented groups by supporting a PI and students in an EPSCoR state institution (The University of Tennessee). This study allows for students to participate in state-of-the-art research in ecology and molecular biology, while furthering their understanding of how science functions in other countries.

2. What may be the **benefits of the proposed activity to society**?

The single most valuable natural resource of any country, especially in North America, is an ample supply of water for its citizens. In the United States surface water resources are critical to supplying of potable, industrial, transportation and commercial needs. This research directly addresses the maintenance and protection of this resource by addressing the single most significant threat to this resource, thereby providing incalculable benefits to society. This project further supports a deeper collaboration with Chinese researchers, benefiting residents of both countries as we strive towards a better understanding of our managed natural resources.

3. How well does the activity **advance discovery and understanding while promoting teaching, training, and learning**?

This project is seeding numerous collaborations and interactions between established US researchers at UNC-CH (NSF Pre-graduate Research Experience Program), The UT-Knoxville (an EPSCoR institution), and those at NIGLAS, other branches of the Chinese Academy of Sciences and Chinese Universities. Exchanges between American and Chinese labs will foster new understandings of how science as a process is undertaken in different cultures, and provide novel opportunities for students and researchers. This project has already led to new collaborative relationships being forged. For example, one of our UNC graduate students, Tim Otten, received separate NSF funding (project ID: OISE-0913942) to spend 8 weeks this past summer living and working alongside our Chinese colleagues as he studied the microbial and molecular dynamics of toxin producing cyanobacteria in Lake Tai.

4. Will the results be **disseminated broadly to enhance scientific and technological understanding**?

Results will be disseminated via publication in international journals. Additionally, the inclusion of students focused on Environmental Science and Studies (UNC-CH's Institute for the Environment) and Science-Journalism (UT's School of Journalism) will facilitate rapid and widespread dissemination of the materials to all levels (K-12, collegiate and general public).

The following **Areas of Emphasis** (**Themes**) for FY 2010 Highlights are included in this research project:

- is **interdisciplinary**, **high-risk**, and **potentially transformative**
- speeds the translation of promising fundamental research into **innovations** that can be commercialized
- is essential to the Nation's **security**, **prosperity**, **economic revitalization**, and job creation
- promotes greater **sustainability** (includes climate change) and green jobs
- enhances **health** and **quality of life**
- nurtures a world-class engineering **workforce** and a **technically literate population**

ENG/CBET 2010

Program Officer: Bruce Hamilton

NSF Award Numbers:

0826819

Award Title:	Collaborative Research: Evaluating Nutrient Reductions to Control Cyanobacteria and Ensure Large Lake Sustainability: Lake Taihu (China) as a Model for North American Systems
Start Date:	09/15/2008
Expires:	08/31/2010
Awarded Amount to Date:	$165,537
PI:	Hans Paerl, hpaerl@email.unc.edu
Institution Name:	University of North Carolina at Chapel Hill

State Code: NC
PE Codes: 7731, 7643

0826838
Award Title: Collaborative Research: Evaluating Nutrient Reductions to Control Cyanobacteria and Ensure Large Lake Sustainability: Lake Taihu (China) as a Model for North American Systems
Start Date: 09/15/2008
Expires: 08/31/2011
Awarded Amount to Date: $111,532
PI: Steven Wilhelm, wilhelm@utk.edu
Institution Name: University of Tennessee Knoxville
State Code: TN
PE Codes: 7643

NSF Contract Numbers:

Entered on 01/07/2010 by Sonya Williams